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ORIGINAL PAPER

Effect of shelterwood cutting method on forest regeneration and stand structure in a Hyrcanian forest ecosystem

Mohammad Reza Pourmajidian • Hamid Jalilvand • Asghar Fallah • Seyed Ataollah Hosseini
Aidin Parsakhoo • Amin Vosoughian • Ali Rahmani

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Abstract: A study was carried out to evaluate the effect of shelterwood cutting methods on stand structure and regeneration density. Data were collected from a northern hardwood forest stands in Iran with *Fagus orientalis* Lipsky as dominant species, with/without shelterwood cutting operation. Results clearly demonstrate that the management of *Fagus orientalis* Lipsky with shelterwood cutting system affected the frequency and diversity of the understory herbaceous species. The frequency of *Viola silvestris* Lam., *Asperula odorata* L., *Carex spp*. and *Rubus hyrcanus* Juz increased significantly after shelterwood cutting. The DBH (diameter at breast height) of commercial species in control stands (57.50±2.15 cm) was greater than that in treated stands (50.67±1.88 cm), whereas the total height of trees was similar between treated and control plots (21±0.5 m). The number of *Parrotia persica* seedlings increased by 13.2% from 1995 to 2005 whereas the number of *Fagus orientalis* and *Carpinus betulus* seedlings significantly decreased from 1995 to 2005. In conclusion, it confirms that instead of shelterwood cutting method other silvicultural practices such as selection cutting method should be applied for the mountainous beech stands of Hyrcanian forests.

Keywords: Shelterwood cutting; stand structure; regeneration; *Fagus orientalis* Lipsky

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Mohammad Reza Pourmajidian • Hamid Jalilvand • Asghar Fallah
Seyed Ataollah Hosseini(✉)
Department of Forestry, Faculty of Natural Resources, Sari Agricultural Sciences and Natural Resources University, Sari City, P.O. Box: 737, Mazandaran Province, IR-Iran. Tel: +98 152 4222984-5, Fax: +98 152 4222982; E-mail: Ata_hosseiny2002@yahoo.com

Aidin Parsakhoo
Department of Forestry, Faculty of Natural Resources, Sari Agricultural Sciences and Natural Resources University, Sari City, Iran.

Amin Vosoughian • Ali Rahmani
Department of Forestry, Faculty of Natural Resources, Mazandaran University, Sari City, Iran.

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Introduction

Hyrcanian or northern forests of Iran stretch up to an altitude of 2800 m a.s.l. and comprise different forest types with 80 species of trees and shrubs. There are 1.9×10^6 ha of hardwood forests in the north of Iran, which is called Hyrcanian ecosystem (Hosseini et al. 2007; Rouhi-Moghaddam et al. 2008; Poorbabaei and Poorrostam 2009). The mean stock of these forests is 280 $m^3\cdot ha^{-1}$ and the annual increment is between 2 and 8 $m^3\cdot ha^{-1}$ (Sagheb-Talebi and Schutz 2002). In this ecosystem, the shelterwood cutting system is one of the traditional methods used to encourage the regeneration of the species with heavy seed such as beech and oak (Granberg et al. 1993; Quinby 2000; Glöde and Sikström 2001). This method was introduced by Hartig in 1791 for central European beech forests. The main objectives of shelterwood cutting are to develope seed trees by natural regeneration and encourage desirable species to achieve their maximum diameter growth (Schlesinger et al. 1993; Brose and Van Lear 1999). Shelterwood cutting system in forest management is a series of partial cuttings that removes the trees during several years and eventually creates a new even-aged stand (Bradley et al. 2001; Brose 2008; De Chantal et al. 2009; Sapkota et al. 2009).

In the common shelterwood cutting system in Iran, preparatory cutting (an optional initial treatment to increase tree vigor and seed production within a mature stand), regeneration cutting (a treatment to establish regeneration throughout the stand area) and light felling are carried out before final cutting (Sagheb-Talebi and Schutz 2002). In regeneration cutting, a percentage of overstory is removed and soil is prepared for natural regeneration (Örlander and Karlsson 2000). Moreover, declining overstory may affect understory moisture and microclimate (Langvall and Löfvenius 2002; Morneault et al. 2004).

An alteration of stand structure will influence the function of the ecosystem including site microclimate, water balance and soil fertility (Drew 1990; Chapman and Chapman 1997; Pothier et al. 2003; Erefur 2007). An experiment about regeneration under the shelterwood of spruce-dominated mature stand, con-

ducted by Souček (2007) in Czech Republic, demonstrated that the diameter growth of 12-year-old sample trees after shelterwood cuttings was more than that of control. Moreover, regeneration density in subsequent forest after shelterwood cutting method was 88% and in control plot 67%.

Soil acidity, nutrient deficient soils, lack of light penetration, herbivore, and understory competition are the major obstacles encountered in regenerating hardwoods (Meiwes et al. 1986; Cronan and Grigal 1995; Paquette et al. 2006). In shelterwood cutting system, light can penetrate to the forest floor (Hannah 1987; Brose and Van Lear 1998; Nagaike et al. 1999). Seedling competition with ferns and grasses to access light and nutrients has been a problem following shelterwood cutting in many European and American countries (Loftis 1990; Brose and Van Lear 1998). During shelterwood cutting in north of Iran, technical deficiency in performing secondary light felling has been caused invasion of berry (*Rubus fructicosus*) and fern (*Petridium aquilinum*) into gaps (Habashi et al. 2007; Pourmajidian et al. 2009).

By changing the shelterwood density, the light condition is greatly changed, which may affect the performance of the seedlings and the outcome of the regeneration (Gordon et al. 1995; Langvall and Örlander 2001). Savoi et al. (1988) reported that the germination in beech was favored by increasing light intensity; more seedlings survived during the first months after emergence. In shelterwood, the height growth of seedlings of Scots pine and Lodgepole pine was significantly reduced due to partially factors associated with the distance to the nearest shelter tree (Strand et al. 2006). In a 130-year-old beech stand of southern Sweden, the beech (*Fagus sylvatica*) seedling germination rate was higher in the shelterwood than in the clear-cut, whereas the increase in seedling height and dry mass was greater in the clear-cut than in the shelterwood (Agestam et al. 2003).

Despite many studies have focused on the changes of natural regeneration in understory plants from the canopy structure of beech, spruce and oak forest by shelterwood cutting (Loftis 1990; Agestam et al. 2003; Souček 2007; Poorbabaei and Poor-rostam 2009; Pourmajidian et al. 2009), the role of this system on regeneration and stand structure of beech forests in Middle East deciduous temperate zone such as Hyrcanian forests is not fully understood. Moreover, evaluating the effectiveness of shelterwood cutting from the perspective of silviculture is especially important to determine the type and time of improvement and tending operations. This paper sought to answer whether or not shelterwood cutting system was successful in our study area by evaluating the effect of shelterwood cutting in 1995 and 2005, in stand structure (tree diameter at breast height and basal area, crown diameter, tree height and volume) and regeneration density.

Materials and methods

Study site

Darab Kola forest with an area of 2 612 ha is located to the southeastern Sari city, Mazandaran Province, Iran (36˚29′19″ to 36˚30′6″N, 53°19′25″ to 53°19′57″ E and 560−750 m a.s.l.). The soil is washed brown with classic horizon and at depth of 110-120 cm. The bed rock has marl, calcareous sandstone and limestone. The general aspect of the hillside is north and its average slope is 40%. The main woody species in Darab Kola are *Fagus orientalis Lipsky*, *Ulmus glabra* Huds, *Acer velutinum* Boiss, *Carpinus betulus*, *Parottia persica* and *Alnus glutinosa L*. The dominant species in our research area is *Fagus orientalis Lipsky*. Herbaceous vegetation in the forest consisted of Asperula (*Asprula odorata*), Ferfion (*Ephorbia sp.*), Metumeti (*Hypericum androseamum*) and fern (*Polystichum sp*.). The climate is very moist with average temperature ranging from 26.1°C in August to 7.5 ºC in February. Mean annual air temperature is 16.7 °C. The region receives 983.8 mm of precipitation annually. Minimum and maximum rainfall is 36.1 to 119.8 mm in July and November, respectively. The growing season lasts 240 days from April to November.

Data collection

Data were collected in 1995 and 2005 from a treated shelterwood without final cutting and control stands were located in 57-ha forest. In treated stand, two phases of shelterwood cutting including preparatory and regeneration cuttings with intensity of 20%-25% were conducted in 1986 and 1991, respectively. In order to define the study area, a topographical map with a scale of 1:5000 was prepared. Sampling was conducted based on a systematic randomized approach. The map was placed on a network with scaled down dimensions of 75m×75m. The 60 circular sample plots in a size of 1 000 m^2 were considered for treated and control stands. In each plot, a 100-m^2 circular micro-plot was established for measuring regeneration density of stands (Fig. 1). Smaller circular subplots with a size of 1 m^2 were set up for surveying herbaceous plants.

Within each plot, the herbaceous plants were recognized and their frequency was calculated based on number of plots that have the species and the number of all plots surveyed. Diameter at breast height (DBH) of all trees in each of plots with a size of 1 000 m^2 was measured by caliper. In addition, DBH and height of four trees (2 trees were the nearest to the plot center and 2 trees were the largest in diameter at breast height) were recorded. Other parameters such as tree total height and basal area, crown basal area, bole height, crown height, crown diameter and crown coverage were calculated. Seedling densities (less than 1.3 m in height) were recorded in each micro-plot. Also, seedling vitality was classified into 4 classes where class 1 included seedlings with very low vitality (more than 60% of leaves were pale), class 2 included seedlings with low to medium vitality (25%−60% of leaves were pale), class 3 included seedlings with relatively high vitality (10%−25% of leaves were pale) and class 4 included seedlings with high vitality (0-10% of leaves were pale).

Statistical analysis

All the data were analyzed statistically by using the computer software packages Microsoft Excel 2003 and SAS version 9.0.

Analysis of variance (ANOVA) was used to determine the effect of management type on stand structure and regeneration. SNK test (Student Newman Kouls) at probability level 5% was used to compare the means. Linear regression was used to calculate the relationships between vegetative parameters.

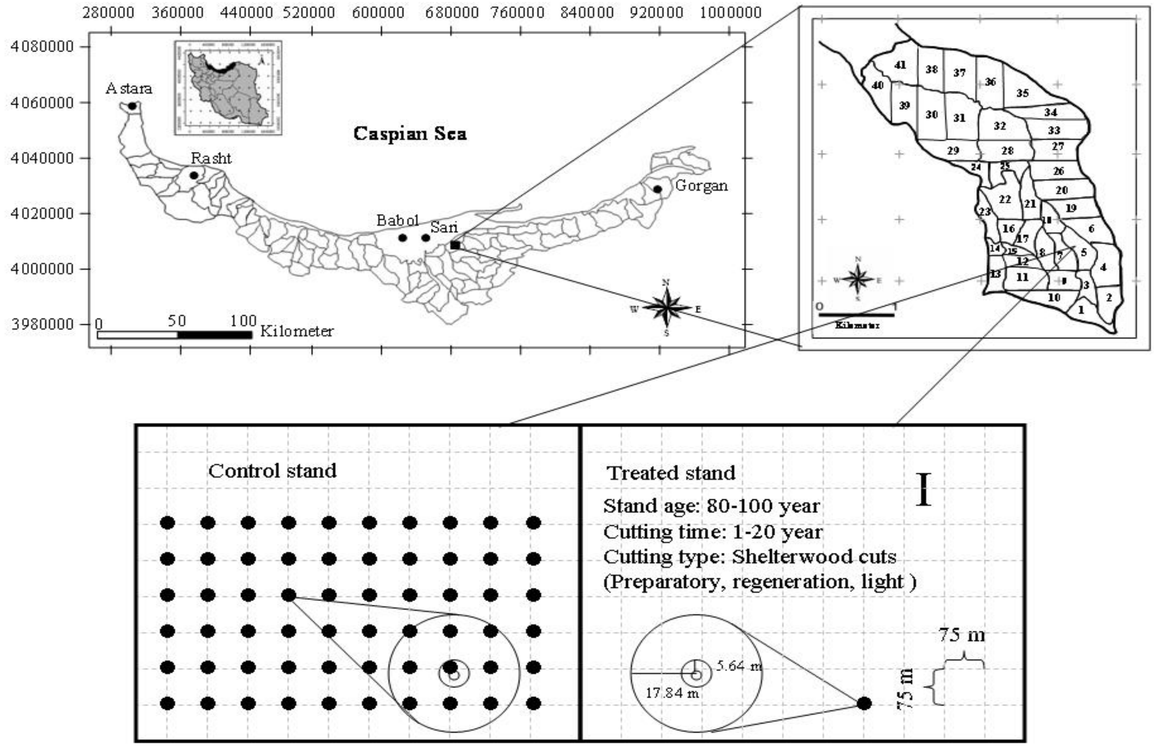

Fig. 1 Geographical position of the study area in northern forests of IR-Iran and schematic of systematic randomizes sampling method in treated and control stands.

Results

Herbaceous and commercial species characteristics

The frequency of *Viola silvestris* Lam., *Asperula odorata* L., *Carex spp*. and *Rubus hyrcanus* Juz increased significantly after the shelterwood cutting in treated stand ($p<0.05$) (Fig. 2). The DBH of commercial species in control stands was greater than that in the treated stands, whereas the total height of trees was similar. The mean bole height of trees in control stands was higher than that in the treated stands. The height and basal area of tree crown in control stand was less than those in the treated stand. The mean basal area at breast height recorded for trees in the control stand (0.30±0.02 m^2) was larger than that in the treated stand (0.23±0.01 m^2), (Table 1).

Stock growth in the treated and control stands

In treated stands, trees density in diameter classes≤60 cm was greater than that in control stands except for diameter classes 25, 35 and 55 cm, whereas trees density in diameter classes > 60 cm in the treated stands was less than that in control stands except for diameter class 75 (Table 2). In the treated stands, tree volume in different diameter classes was more than that in control stands except for diameter classes 25, 80, 85, 95, 100 and 105 cm (Table 3).

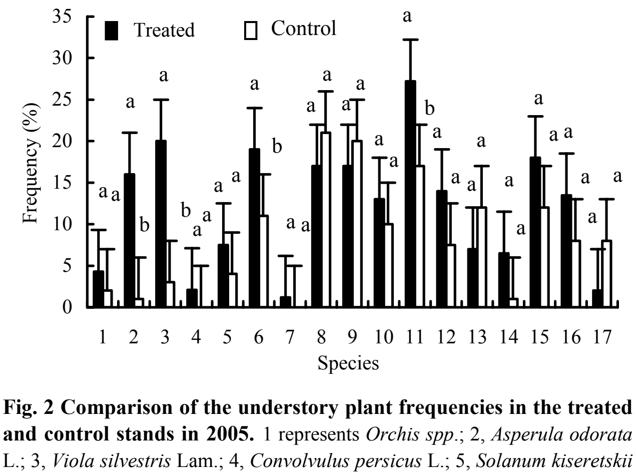

Fig. 2 Comparison of the understory plant frequencies in the treated and control stands in 2005. 1 represents *Orchis spp*.; 2, *Asperula odorata* L.; 3, *Viola silvestris* Lam.; 4, *Convolvulus persicus* L.; 5, *Solanum kiseretskii* C.A.Mey.; 6, *Rubus hyrcanus* Juz.; 7, *Fragaria spp*.; 8, *Pteridium aquilinum* (L.) Kuhn.; 9, *Hedera pastuchovii* Woron.ex.; 10, *Euphorbia amygdaloides* L.; 11, *Carex spp*.; 12, *Ruscus hyrcanus* Woron.; 13, *Geraminea spp*., 14, *Lamium album* L.; 15, *Hypericum androsaemum* L.; 16, *Panicum undolatifolius* Ard.; 17, *Danae racemosa* (L.) Moench. Letters a and b show significance between treatments based on SNK test (Student Newman Kouls) at probability level of 5%.

The proportion of *Fagus orientalis* L. in the treated and control stands was significantly greater than that of other species (Table 4), but no significant difference was detected among species densities in different treatments (Table 4). Regression analysis detected a strongly positive relationship between tree height and diameter at breast height in treated (R^2=0.76) and control stands (R^2=0.64), (Table 5).

Table 1. Means and standard deviation for commercial species in the treated and control stands in 2005

Plots	DBH (cm)	Total height (m)	Bole height (m)	Crown height (m)	Crown basal area (m^2)	Basal area at breast height (m^2)
Treated	50.67±1.88	21.78±0.56	8.01±0.36	13.16±0.53	48.95±3.24	0.23±0.01
Control	57.50±2.15	21.11±0.53	10.43±0.41	11.34±0.46	45.92±3.18	0.30±0.02

Table 2. Comparison of the trees densities (Tree·ha^{-1}) in different diameter classes in the treated and control stands

Plots	Diameter classes (cm)																		
	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105
Treated	7	10	2	11	7	7	5	11	5	14	14	9	10	3	2	1	2	0	0
Control	5	1	9	9	9	4	4	4	6	13	16	13	7	6	5	3	5	3	3

Table 3. Comparison of the tree volumes (m^3·ha^{-1}) in different diameter classes in the treated and control stands

Plots	Diameter classes (cm)																		
	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105
Treated	0.6	2	0.6	6.3	6.4	9	8.6	25	13	43	57	46	60	20	16	10	20	0	0
Control	0.2	0	1.7	2.0	3.8	4	3.4	3.8	8.8	23	36	33	22	25	17	8	22	23	15

Table 4. Comparison of different species densities (Tree·ha^{-1}) in the treated and control stands

Plots	*Acer velutinum*	*Acer laetum*	*Alnus subcordata*	*Fagus orientalis*	*Ulmus glabra huds*	*Carpinus betulus*	*Parrotia persica*
Treated	3^a	1^a	5^a	100^a	2^a	8^a	0^a
Control	9^a	0^a	0^a	103^a	1^a	4^a	3^a

Note: "a" shows the same groups according to SNK test (Student Newman Kouls) at probability level of 5%.

Table 5. Linear regression analysis between the trees diameter (DBH), Crown basal area (CA), Bole height (BH), Crown height (CH), Total height (TH) and basal area (BA).

Plots	Dependent variable	Independent variable	Reg. coefficients b_0	Reg. coefficients b_1	CEC	R^2	aR^2	CV	SSR	Press
Treated	CA	DBH	-0.30^{ns}	1.03^{***}	0.06	0.4	0.4	15.6	37.7	38.9
Control	CA	DBH	-0.73^{*}	1.09^{***}		0.5	0.5	13.9	29.0	30.0
Treated	CA	CH	1.22^{***}	0.98^{***}	0.03	0.4	0.4	15.7	38.1	39.2
Control	CA	CH	1.39^{***}	0.94^{***}		0.4	0.4	15.7	37.4	38.6
Treated	BH	TH	-0.19^{ns}	0.71^{***}	0.24	0.2	0.2	24.1	25.9	26.7
Control	BH	TH	-0.67^{*}	0.96^{***}		0.4	0.4	17.7	18.5	19.2
Treated	TH	DBH	0.63^{***}	0.63^{***}	0.08	0.8	0.7	5.8	3.5	3.7
Control	TH	DBH	0.89^{***}	0.54^{***}		0.6	0.6	6.4	4.5	4.7
Treated	CA	BA	-0.18^{ns}	0.51^{***}	0.03	0.4	0.4	15.6	37.7	38.9
Control	CA	BA	-0.60^{**}	0.54^{***}		0.5	0.5	13.9	29.0	30.0
Treated	CH	TH	-1.04^{***}	1.16^{***}	0.13	0.6	0.6	12.7	11.5	11.9
Control	CH	TH	-0.80^{**}	1.03^{***}		0.5	0.5	15.1	14.6	15.1
Treated	CA	TH	-0.17^{ns}	1.27^{***}	0.15	0.3	0.3	17.0	44.9	46.5
Control	CA	TH	-0.71^{ns}	1.42^{***}		0.4	0.4	15.6	36.9	38.4

Notes: In Table 5 CEC (summarized statistics) is comparison of the error coefficients, aR^2 is adjacent R-square, SSR is residual sum of square, PRESS is estimated residual sum of square and CV is coefficient of variation.

Stock growth in 1995 and 2005

In shelterwood cutting system, *Fagus orientalis* Lipsky density in different diameter classes in 1995 was approximately similar to that in 2005 (p>0.05) (Fig. 3a), but its basal area (Fig. 3b) and volume per hectare (Fig. 3c) in 1995 were more than those in 2005 (p<0.05). Other species density in 1995 and 2005 was approximately similar (p>0.05) (Fig. 3d). Other species basal area

(Fig. 3e) and volume per hectare (Fig. 3f) with DBH ≤ 45 cm in 1995 were more than those in 2005 (p<0.05). *Carpinus betulus* L. density (Fig. 3g), basal area (Fig. 3h) and volume per hectare (Fig. 3i) in different diameter classes in 2005 were significantly less than those in 1995. These indexes were also observed for total species (Fig. 3j), especially for basal area (Fig. 3k) and volume per hectare (Fig. 3l). So, the stock of commercial species especially *Carpinus betulus* was decreased from 1995 to 2005.

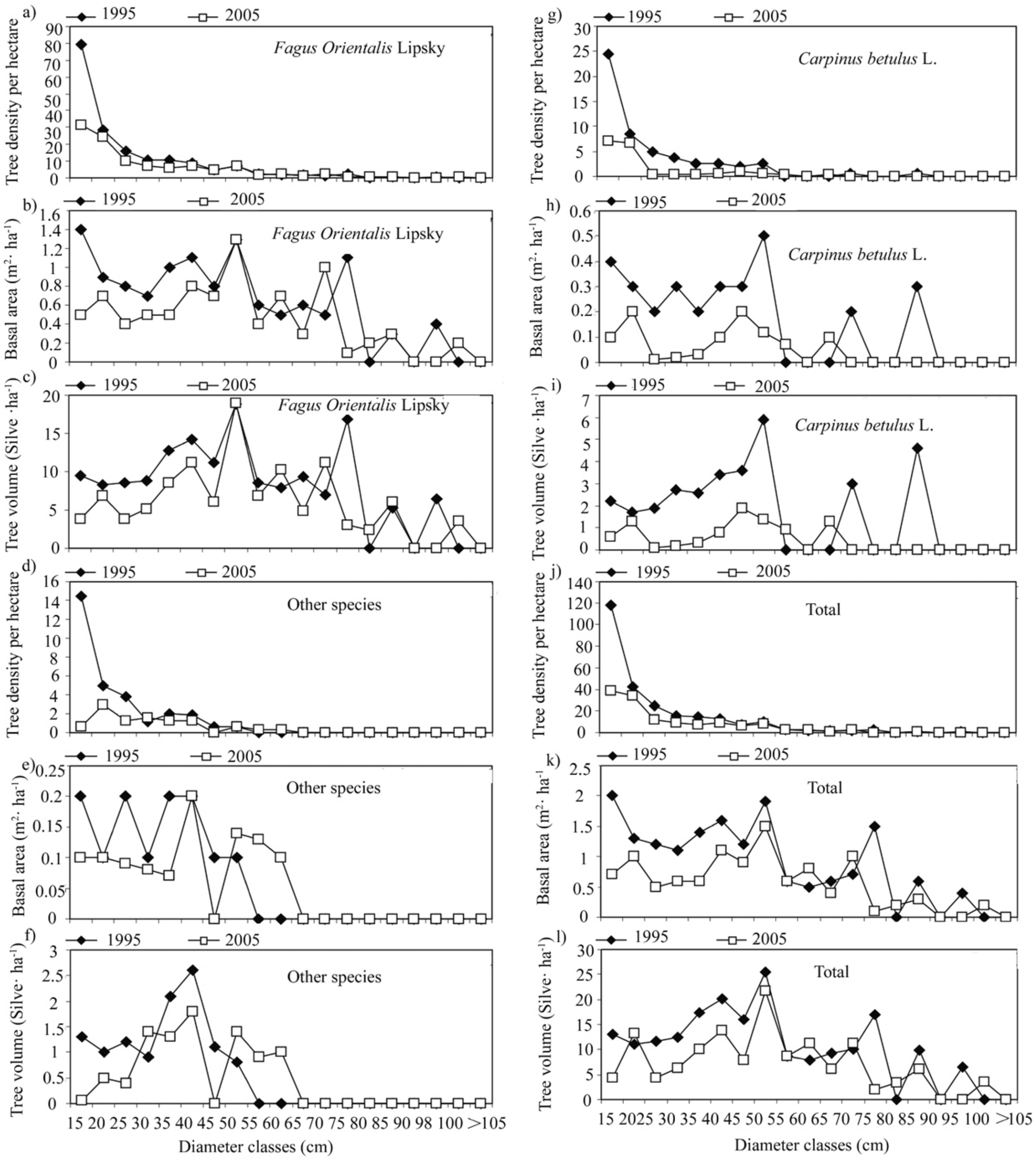

Fig. 3 Comparison of the trees density, basal area and volume per hectare between two time treatment 1995 and 2005 for *Fagus orientalis* Lipsky, *Carpinus betulus* L., total and other species.

Regeneration in the treated and control stands

The most regeneration density with vitality class 1 and 2 was observed in control stands, whereas regeneration density with vitality class 3 in the treated stands was more than that in control stands. For both stands, there was no significant difference between regeneration densities in vitality class 4 (high vitality), (Fig. 4, Table 6).

Regeneration in 1995 and 2005

The *Parrotia persica* seedling densities in 2005 were signifi-

cantly more than those in 1995 (p<0.05). The seedling densities for *Fagus orientalis* were 83% in 1995 and 75.3% in 2005 (P<0.05). Furthermore, the *Carpinus betulus* seedling densities were 11.3 % in 1995 and 2% in 2005 (p<0.05) (Table 7).

Table 6. Regeneration density (Number·ha^{-1}) for different species in treated and control stands

Species	Height <1.30 m		Diameter classes (cm)					
			0–2.5		2.5–7.5		7.5–12.5	
	Treated	Control	Treated	Control	Treated	Control	Treated	Control
Acer velutinum	12	9	4	0	0	0	2	0
Acer laetum	20	32	20	3	0	5	0	0
Parrotia persica	288	62	192	23	46	7	14	0
Quercus castaneifolia	5	1	2	0	0	0	0	0
Diospyros lotus	17	19	8	1	4	8	1	0
Fagus orientalis	995	165	122	64	96	59	28	8
Carpinus betulus	47	17	4	0	17	0	14	2

Table 7. Regeneration density (%) for different species in 1995 and 2005

Species	Height <1.30 m		Diameter classes (cm)						Total	
			0–2.5		2.5–7.5		7.5–12.5			
	1995	2005	1995	2005	1995	2005	1995	2005	1995	2005
Acer velutinum	0.1	0.1	0	0.01	0	0.01	0	0.01	0.1^{a}	0.13^{a}
Acer laetum	0	0.07	0	0	0	0	0	0	0^{a}	0.07^{a}
Parrotia persica	0.3	9.9	1.8	3.4	2.6	3.2	0.1	1.5	4.8^{b}	18^{a}
Quercus castaneifolia	0	2.1	0	0	0	0	0	0	0^{a}	2.1^{a}
Diospyros lotus	0.8	1.6	0	0.1	0	0.2	0	0.3	0.8^{a}	1.7^{a}
Fagus orientalis	18	27.7	31.4	21.6	21.5	15.6	12.4	10.3	83^{a}	75.3^{b}
Carpinus betulus	2	1	2	0.6	3	0.4	4.3	0.2	11.3^{a}	2.2^{b}

Notes: in a same row, values with same superscript aren't significantly different at 5% level of SNK test.

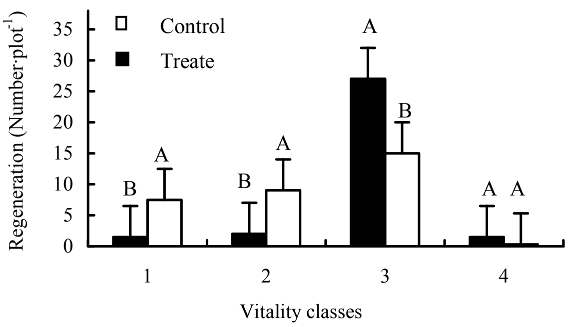

Fig. 4 Regeneration density in different vitality classes of the treated and control stands. A and B show different groups according to SNK test (Student Newman Kouls) at probability level of 5%.

Discussions

The shelterwood cutting system can be used to establish regeneration and to improve the growing conditions of seedlings and, thereby, increase their probability of survival after final harvest (Pothier and Prévost 2008). One of the features of shelterwood cutting method is maintaining forest canopy at some degree, which can reduce harvesting damage to forest ecosystem. Although shelterwood harvesting is deemed to be adequate for preserving some wildlife values, little is known about its impact on stand structure and forest regeneration (Bradley et al. 2001).
Management of *Fagus orientalis* Lipsky with shelterwood cutting system affected the frequency and diversity of the understory species. The frequency of *Viola silvestris* Lam., *Asperula odorata* L., *Carex spp*. and *Rubus hyrcanus* Juz increased significantly after the shelterwood cutting in the treated stand (Fig. 2). This strong increase in the plant density was due to the canopy opening after harvesting. So, the shelterwood cutting system seems to be an option for maintaining plant species diversity after logging. Similar findings have been reported for *Fagus orientalis* Lipsky in Sangdeh forests of Iran (Pourmajidian et al. 2009). Decrease of frequency for some shade tolerance species such as *Hedera pastuchovii* Woron.ex. and *Danae racemosa* (L.) Moench was recorded in the treated stand (Fig. 2). This species might disappear due to the exposure to greater sun light. Shelterwood cutting has been reported to make beech regeneration more difficult in many Japanese beech forests, but this method might not significantly affect plant species diversity (Nagaike et al. 1999).

In this study, it has been proven that DBH of commercial species in control stands is more than that in the treated stands, whereas the total height of trees is similar between the treated and control plots (Table 1), which is agreed with other recent results (Sagheb-Talebi and Schütz 2002; Sagheb-Talebi et al. 2004). In addition, the bole height of trees in control stands was higher than that in the treated stands (Table 1). In the treated stands, the bole branchiness can be increased because of human interference and solar radiation entering into the stands. The height and basal area of tree crown in the control stands were less than those in the treated stands (Table 1). This could confirm that the bole height in control stands was higher than that in the treated stands (Strand et al. 2006).

The mean basal area at breast height recorded for each tree in treated and control forests was (0.23±0.01) m^2 and (0.30±0.02) m^2, respectively (Table 1). This is in agreement with the findings of Tabari et al. (2007). A study was carried out before the first shelterwood cutting (in 1974) and after the last shelterwood cutting (2004) in a *Fagus orientalis* forest in north of Iran. The results after 30 years (in 2004) revealed that frequency, basal area and standing volume were significantly enhanced for beech and reduced for hornbeam but did not statistically differ for alder, maple and other species. Sapling and thicket groups were observed in parts of the investigated site, where the mature trees were not felled (Tabari et al. 2007). In the treated stands, trees density in diameter classes of ≤ 60 cm was greater than that in control stands (Table 2). Also, trees volume in diameter classes of ≥ 80 cm in treated stands was less than that in control stands (Table 3), because in the first cuts of the shelterwood, the trees with the most original basal area were harvested (Habashi et al. 2007).

The seedling vitality in the control stands was less than that in the treated stands (Fig. 4), which is in accord with previous results of Agestam et al. (2003) and Beguin et al. (2009). The reason may be that seedling vitality in gaps of treated stands was more than that in the closed canopy of control stands. Another explanation can be the accessibility of light for seedlings in gaps (Loftis 1990; Erefur 2007; Sapkota et al. 2009). In clear-cuts the height of red spruce (*Picea rubens* Sarg.) seedlings in skid trails seemed to be negatively affected by the considerable quantity of woody debris (Pothier and Prévost 2008).

Unsuitable harvesting methods during last 30 years and lack of forest protection are the two main technical reasons for failure of the shelterwood cutting system in Hyrcanian forests (Hosseini et al. 2000; Soltani 2003). In addition, infrequent seed years occurring at intervals of five to eight years and closed canopy are natural reasons of regeneration failure in shelterwood cutting system of Hyrcanian forests (Soltani 2003). This incomplete regeneration was also observed in shelterwood cutting system of European forests. So, artificial planting was prescribed to supplement natural regeneration (Linnard 1987; Shimano and Masuzawa 1998).

Holgén and Hånell (2000) recommended that the density of shelter conifer trees should be at least 200 per hectare to provide adequate protection for the new tree generation. Beguin et al. (2009) demonstrated that the use of silvicultural treatments (shelterwood cutting and strip clear cutting) alone is unlikely to restore balsam fir regeneration on Anticosti Island. In this study, the number of *Parrotia persica* seedlings in 2005 was significantly more than that in 1995 (Table 7), which supports Soltani (2003) results. *Fagus orientalis* and *Carpinus betulus* seedlings significantly were decreased from 1995 to 2005 (Table 7). A similar response has been found in other researches (Tabari et al. 2007).

Conclusions

We found that the density of *Fagus orientalis* and *Carpinus betulus* seedlings significantly decreased from 1995 to 2005, whereas *Parrotia persica* seedlings density increased. These findings indicate that shelterwood cutting system was not a suitable method for the management of beech forests in our study area due to topography restrictions. Moreover, present study results reveal that the frequency of *Rubus hyrcanus* Juz increased significantly after the shelterwood cutting in the treated stand because of unsuitable secondary thinning that has caused invading berry (*Rubus hyrcanus* Juz.) in gaps. In conclusion, it confirms that, instead of shelterwood cutting system, other silvicultural practices, such as single tree selection system and group selection system, should be applied for the mountainous beech stands of the Hyrcanian forests of Iran. Also, despite a large number of studies show that nutrient availability and microbial properties of forest soil are affected by shelterwood system, there are still not enough indications of the effect of this system on the natural regeneration and stand structure. Hence, still further studies are required to provide a better understanding of shelterwood cutting successfulness in deciduous Hyrcanian forests ecosystem as a key control factor on the forest regeneration and stand structure.

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